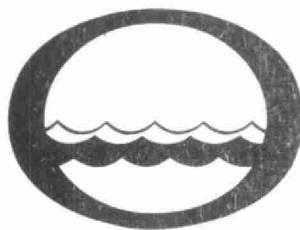ENGLISH R
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Water management in Ontario

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Wabigoon River

below dryden

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river basin
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surveys program

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A WATER USE STUDY

OF THE

WABIGOON RIVER

Ontario Water Resources Commission
1970

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CHAPTER I

SUMMARY AND RECOMMENDATIONS

Wastewaters from the Dryden Paper Company Limited containing
71,000 pounds of suspended solids and 33,000 pounds of BOD_5 (average
daily values measured in September 1968) seriously pollute the Wabigoon
River. Suspended solids composed primarily of wood fibre and bark
blanketed the streambed for many miles below the plant and formed
unsightly and malodorous islands and banks for the first five miles
along the river. Foam, unnatural colour and odours were noticeable
54 river miles downstream in Clay Lake where a commercial and sport
fishery has been practically eliminated because of pollution and
related tainting of fish flesh.

The dissolved oxygen (DO) content of the river was depressed
from Dryden to Clay Lake, and average values as low as 1.7 mg/l were
observed immediately above the confluence with the Eagle River which
is 28 river miles from the paper mill. A recently published biological
survey found only pollution-tolerant organisms in the streambed over
the 28 miles with improvement noticeable below the junction with the
Eagle River.

A study of the total organic pollution load, composed of the
daily mill waste discharge and the accumulated sludge deposited in
the first 28 river miles below the mill, indicates that about one-quarter

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of the total oxygen demand exerted over this length of the river is caused by the sludge deposits.

Assuming complete cessation of the waste discharge from the mill, it was estimated that the sludge deposits are of sufficient magnitude to cause continuing pollution of the river. Nevertheless, satisfactory water quality conditions could be maintained if a large reduction was made in the mill waste load and extensive removal of the accumulations of sludge on the river bed were made. However, it is unlikely that contemporary waste treatment technology will be sufficient to obtain the necessary reductions in the waste load from the mill; streamflow augmentation and in-stream aeration will probably be required to achieve completely the necessary improvements.

While it is recognized that the ultimate dissolved oxygen level for the Wabigoon River should be 5.0 mg/l in order to restore water quality conditions for aquatic life and thereby accommodate water uses other than waste disposal, it is unlikely that this can be achieved with present paper mill waste treatment technology. As an initial objective to obtain a minimum dissolved oxygen level in the river of 4.0 mg/l, it is recommended that:

(a)   the mill reduce the BOD_5 in the effluent by
        at least 80 per cent and decrease the sus-
        pended solids concentration in the effluent
        to a maximum of 50 mg/l. The control program
        should make provision for reduction of those

waste components which have an adverse
effect on aquatic life and cause discolour-
ation, odour and foaming in the river.

(b)   accumulated sludges extending over the
first 28 miles of the river downstream from
the mill should be removed, where possible.

(c)   streamflow augmentation to a minimum of
400 cfs should be provided.

(d)   effluent storage during low flow periods should
be provided.

(e)   depending on the degree of success with item (a)
and as a possible alternative to (c), the provision
of in-stream aeration should be considered.

As a longer term objective, the industry should plan a paper mill

waste treatment program which would achieve a dissolved oxygen

standard of 5.0 mg/l.

Ultimately, the industry should curtail the discharge of oxygen-

consuming wastes to a degree that one-third of the river's capacity to

assimilate wastes is held in reserve for allocation to conservation and

future potential users.

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CHAPTER II

WABIGOON RIVER BASIN

INTRODUCTION

The Wabigoon River, which is part of the Nelson River system, commences at Lake Wabigoon about one-half mile upstream from the Town of Dryden. The river flows in a north-westerly direction and is joined by the Eagle River before its confluence with the English River.

WATER USES

Water Supply

The Town of Dryden (population 6,730[1]) utilizes the Wabigoon River for its municipal water supply. The water is filtered, chlorinated and fluoridated before being distributed to the town.

The Dryden Paper Company Limited uses the river to supply water for mill processing purposes, approximately 30 million gallons per day.

Hydro-Electric Power

Two hydro-electric power developments on the Wabigoon River system are owned and operated by the Dryden Paper Company Limited to produce power for the Dryden mill. One of these developments is

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[1] Ontario Department of Municipal Affairs, 1969.

located on the Wabigoon River approximately four miles below the mill (Wainwright Dam) and the other on the Eagle River at the community of Eagle River. These dams serve to regulate the levels of Lake Wabigoon and Eagle Lake and control the flows in each river.

Fishing and Wildlife

A hunting and fishing camp on Clay Lake utilizes the section of the river below Clay Lake for game fishing and hunting. Clay Lake supported a commercial fishery at one time. No use is made of the river from the mill to Clay Lake other than for waste disposal by the Dryden Paper Company Limited and the Town of Dryden.

WASTE DISPOSAL

The Dryden Paper Company Limited produces approximately 550 tons per day of pulp. The effluents from the mill processes are discharged to a lagoon which serves as a foam trap and provides limited settling before the waste is discharged to the river. Untreated sanitary wastes from the mill are discharged directly to the river with the mill effluent.

Domestic wastes from the Town of Dryden are treated at a 1.0 U.S. mgd modified activated sludge sewage treatment plant. The effluent is discharged to the Wabigoon River approximately one mile below the mill outfall.

STREAMFLOW

The records of discharge in the Wabigoon and Eagle rivers

controlled by the company are not kept in a format that permits ready

determination of daily average streamflows. Alternatively, a chart

showing monthly average discharges at Dryden for the period 1930

to 1962, obtained from the Ontario Department of Lands and Forests,

was used. The monthly regulated flows released from the dam at

Dryden were analyzed and the following results obtained: (all

figures are accurate to $\pm$ 25 cfs).

Monthly Low Flows – May to October Period (31 yrs.)

	Per Cent Equal to or Greater Than			
	80%	85%	90%	95%
Minimum Regulated Monthly Average Low Flows (cfs)	220	205	190	165

Over a twelve month period monthly flows have equalled or

exceeded 200 cfs 93 per cent of the time (1930 – 1961).

During the field survey, the discharges of the Wabigoon River

at Dryden and the Eagle River at its confluence with the Wabigoon,

a tributary some 28 miles downstream from Dryden, were 635 cfs

and 630 cfs respectively.

CHAPTER III

SURVEY OF WASTE LOAD AND WATER QUALITY

SCOPE OF SURVEY

Surveys were conducted in August and September 1968 commencing at Dryden and continuing downstream to the outlet of Clay Lake, a distance of 61 miles.

River travel times were determined using stream cross-sections and discharge measurements and confirmed with dye tracing (Rhodamine WT) techniques. Measurements were made of dissolved oxygen, water temperature, BOD_5, and solids and the nutrients nitrogen and phosphorus along the river and at various locations in Clay Lake (Figure III-1).

POLLUTION LOAD AND EFFECT ON WATER QUALITY

During the September survey, the company discharged a BOD_5 load which fluctuated from 22,000 pounds to 57,000 pounds per day and averaged 33,000 pounds BOD_5 per day in an average waste discharge volume of 28.7 million gallons per day (mgd). The suspended solids loading averaged 71,000 pounds per day.

By comparison, the Dryden sewage treatment plant discharged 24 pounds BOD_5 per day and 150 pounds per day of suspended solids in a flow of 1.0 U. S. mgd.

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FIG. III — I
WABIGOON RIVER
SAMPLING STATION LOCATIONS
DWG. Nº: 69 – 128 – RB
AUG. 1969 L.B.

LEGEND

— ⑫ — DAYTIME SAMPLING POINT

— Ⓗ — CONTINUOUS SAMPLING POINT
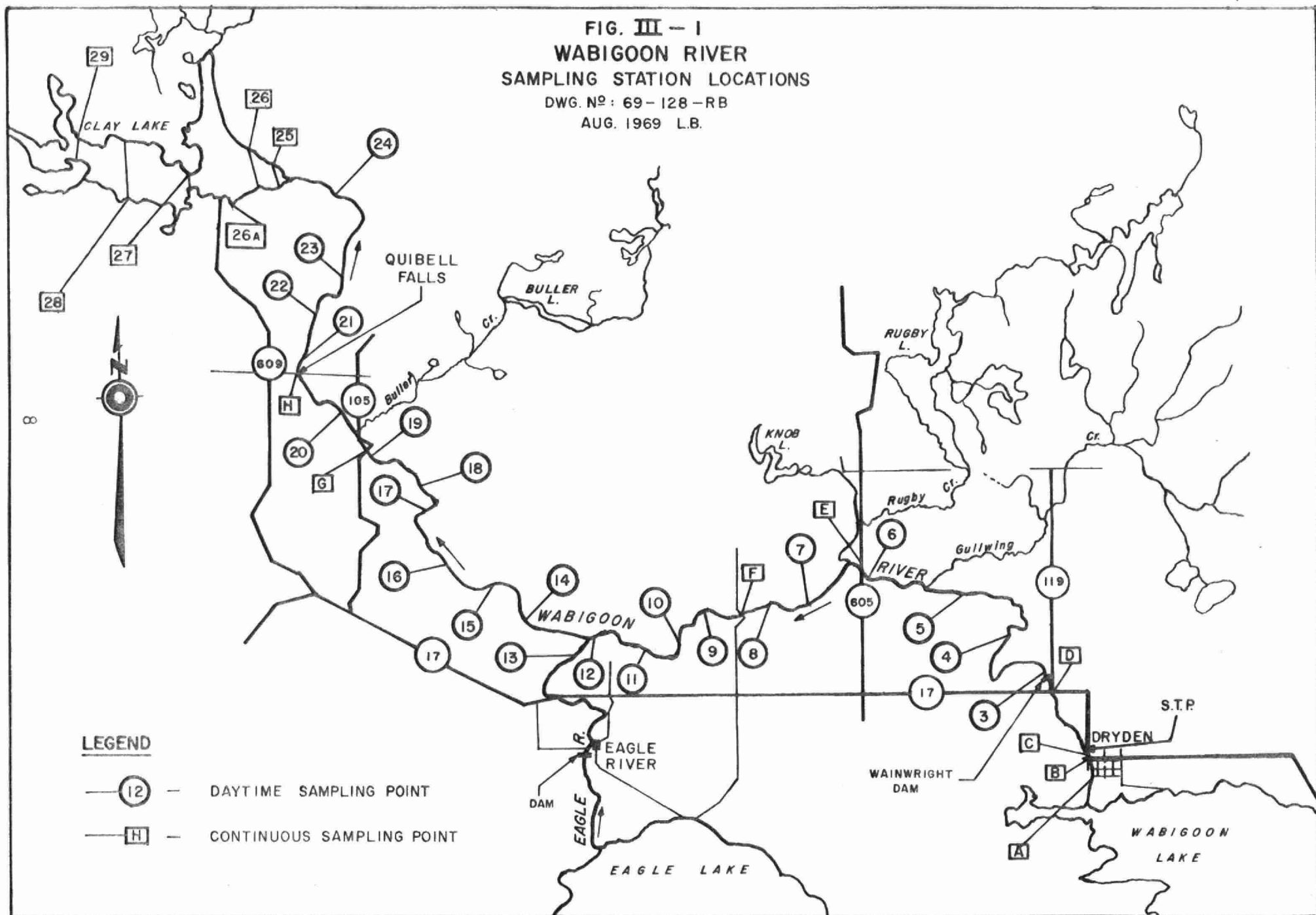
BIOCHEMICAL OXYGEN DEMAND (BOD) AND
DISSOLVED OXYGEN (DO)

The BOD content of the river decreased downstream from the
mill for a distance of 12 miles increasing thereafter until the con-
fluence with the Eagle River. The increase was believed to be due
to resuspension of sludge deposited previously on the streambed.

A classical case of oxygen depletion occurred in the river
downstream from the point of addition of the mill waste, (the dissolved
oxygen profile is presented in Appendix B). Above the mill, the
dissolved oxygen averaged 7.7 mg/l (water temperature of 17.5
degrees Centigrade), while downstream, the mill wastes reduced
the dissolved oxygen to 1.7 mg/l at river Mile 28 immediately up-
stream from the Eagle River.

The beneficial effects of the Eagle River (dissolved oxygen
content of 8.0 mg/l) and the reaeration provided by the downstream
rapids and falls raised the dissolved oxygen to 8.6 mg/l at Mile 44
below Quibell Falls. This level of dissolved oxygen was slowly
depleted to an average concentration of 5.2 mg/l at the outlet of
Clay Lake. Horizontal stratification of the lake was evident with
depletion of dissolved oxygen and decreased temperatures en-
countered with increasing depth. The lowest dissolved oxygen value
found in the bottom waters of the lake was 0.4 mg/l.

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Bottom Deposits, Foam and Fibre Mats

The suspended solids load discharged from the mill contributed to sludge deposits and floating mats as far downstream as river Mile 40. Pulp wastes were observed to blanket the entire river bottom to a distance of 28 miles below the mill and isolated deposits were common downstream to the 39 mile range.

In the lower stretches of the river above Clay Lake, gases of decomposition of the settled solids produced offensive odours along the edge of the river and foam, unnatural colour and odours were noticeable in Clay Lake.

Aquatic Life

Only pollution-tolerant aquatic organisms were found in the streambed over the first 28 miles below the mill with improvement noticeable only downstream from the junction of the Eagle River. Fish life was absent in the river from the mill downstream to Mile 40 where coarse fish were observed (OWRC biology survey, June, July 1968).

ORGANIC LOAD

In determining the acceptable waste load and thereby the amount of reduction of the existing load required to satisfy dissolved oxygen requirements in the stream, it was necessary to evaluate the

effect of the sludge deposits on the oxygen resources of the river.

An oxygen demand of 3.6 $g/m^2/day$ was used for this evaluation.

It should be noted that under the present conditions with the sludge

demand and a probable low streamflow of 200 cfs, a dissolved oxygen

content of 4.0 mg/l could be maintained only if no wastewaters were

discharged by the mill.

The significance of the sludge deposits presently accumulated

on the streambed can possibly be best appreciated from another pers-

pective. If one were to consider the magnitude of an acceptable

waste load if the sludge accumulations did not exist, i.e. a situation

where a new paper mill was proposed and there was no previous use

of the stream for waste disposal, a waste load of about 3,900 lbs/day

of BOD_5 would protect the 4.0 mg/l dissolved oxygen objective. If a

dissolved oxygen level of 5.0 mg/l were used, the waste load would

have to be limited to 2,800 lbs BOD_5 per day. During the survey, the

sludge demand represented in the order of 25 per cent of the total

oxygen demand exerted on the first 28 miles of the river downstream

from the mill. These findings emphasize the need for the removal of

paper mill solids from the river bed. While for esthetical reasons

sludge should be removed from the river between the mill and the

Wainwright Dam, restoration of acceptable water quality conditions

would be accelerated with removal of the sludge from the first 28 miles

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downstream from the mill.

A mill loading of 10,000 pounds BOD_5 per day might be practicable today considering the reductions possible with present technology, i.e. about 80 per cent. However, to protect the 4.0 mg/l dissolved oxygen objective such a BOD_5 loading would only be possible if streamflows in excess of 750 cfs could be maintained. If the sludge demand could be discounted, satisfactory assimilation of the 10,000 pounds BOD_5 per day would only be possible under a reliable streamflow of 500 cfs. Acceptable BOD_5 loadings satisfying dissolved oxygen objectives of 4.0 and 5.0 mg/l are presented in Figure III-2. In order to illustrate the effect of the proposed sludge removal on the magnitude of the acceptable BOD_5 loading, a second set of curves are included in this figure.

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FIGURE III-2

WABIGOON RIVER ALLOWABLE LOADINGS

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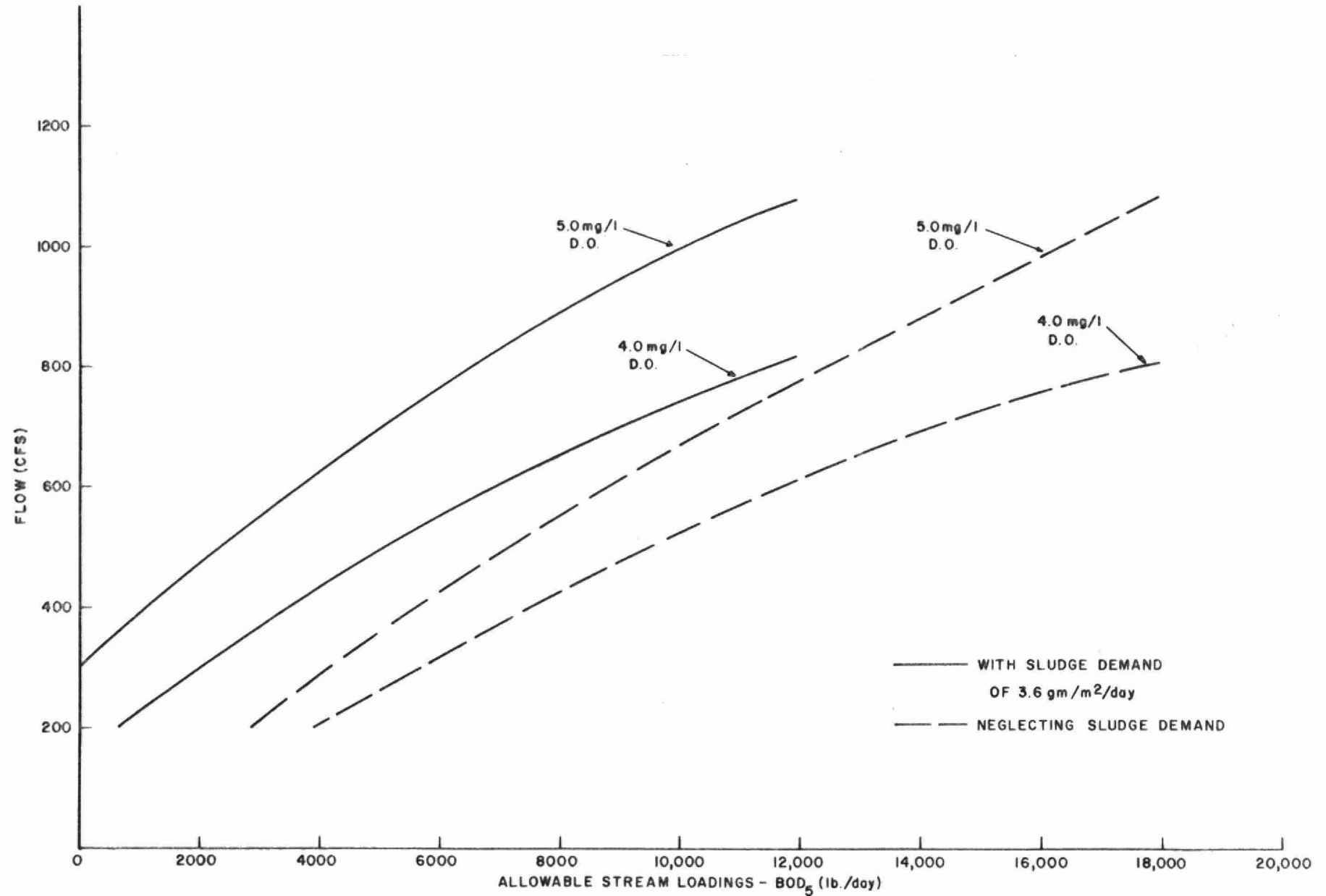
CHAPTER IV

SUGGESTED POLLUTION CONTROL PLAN

In view of the liability caused by the previous accumulations
of mill sludge on the river bed, and recognizing the limitations of
existing waste treatment technology, the first objective should be to
restore dissolved oxygen levels to a minimum of 4.0 mg/l. This
will only be possible by implementation of a combination of the
following procedures:

1.   Waste removal facilities designed to
achieve a minimum reduction of BOD_5
of 80 per cent and a maximum suspended
solids content in the effluent of 50 mg/l.

2.   Where possible, removal of the accumu-
lations of sludge from the first 28 miles
of the Wabigoon River downstream from
the mill.

3.   Streamflow augmentation during natural
low flow periods.

4.   Effluent storage during low flow periods;
and,

5.   In-stream aeration.

While the above measures can be expected to improve the
fishery in the river system and restore the esthetic qualities of the
river, additional measures may be required to remove those waste
components responsible for odours, the tainting of fish flesh and

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improvement of the dissolved oxygen to a level of 5 mg/l. The latter would likely become possible with progressive improvements in waste treatment and will depend in large measure on the success of removing the present accumulations of sludge from the river bed.

The mill and municipality are presently the only users of the river for waste disposal and the industry utilizes the river beyond its capability for self-purification. The suggested pollution control measures are expected to eventually restore the river's quality to acceptable standards. However, it is an unsound practice to allow any one major user the entire capacity of the river. An unused reserve should be provided for other possible waste discharges and conservation purposes. As a long term objective, the industry should therefore direct its pollution control efforts to reserve one-third of the river's capacity to assimilate oxygen demanding wastes for future potential uses while the remaining two-thirds can be used by the industry.

APPENDIX A

WATER QUALITY SURVEY DATA

TABLE I

WATER QUALITY DATA

STATION	LOCATION	NO. SAMPLES	D O	TEMP. °C	BOD₅	COD	SOLIDS			PHOSPHORUS		NITROGENS			
							TOT.	SUSP.	VOL.	TOT.	SOL.	F. A.	KJEL.	N O₂	N O₃
A	UPSTREAM	18	7.7	17.5	1.8	25	124	14	3	0.19	0.15	0.33	0.94	0.016	0.06
B	MILL EFFLUENT	21	-	-	116.0	634	1309	246	141	1.1	0.39	0.74	1.8	0.086	0.09
C	BRIDGE	16	7.1	18.3	4.8	68	209	61	20	0.24	0.13	0.29	0.75	0.017	0.03
STP	DRYDEN	7	-	-	3.2	36	292	20	7	12.5	8.7	1.3	1.9	0.062	3.4
D	MILE 3	16	5.6	18.2	4.1	60	207	38	14	0.29	0.12	0.25	0.84	0.017	0.02
3	" 4	12	6.9	18.4	4.3	65	210	30	8	-	-	-	-	-	-
4	" 8	12	5.4	18.6	3.8	58	195	31	8	-	-	-	-	-	-
5	" 12	12	4.1	18.6	2.9	61	203	26	7	-	-	-	-	-	-
E	" 16	15	3.1	18.2	2.3	55	194	32	7	0.30	0.14	0.23	0.91	0.016	0.02
6	" 16.5	12	3.2	18.3	-	-	-	-	-	-	-	-	-	-	-
7	" 18	12	3.1	18.3	-	-	-	-	-	-	-	-	-	-	-
8	" 20	12	2.8	18.2	2.4	51	180	27	5	-	-	-	-	-	-
F	" 21	14	2.7	18.1	2.5	53	198	29	6	0.26	0.10	0.24	1.1	0.016	0.02
9	" 22	12	2.2	18.1	-	-	-	-	-	-	-	-	-	-	-
10	" 24.5	12	2.1	18.2	2.9	55	182	23	4	-	-	-	-	-	-
11	" 26	12	2.0	18.1	-	-	-	-	-	-	-	-	-	-	-
12	" 28	12	1.7	18.1	3.0	50	171	20	5	-	-	-	-	-	-
13	EAGLE RIVER	12	8.0	18.2	1.0	27	60	6	2	-	-	-	-	-	-
14	MILE 30	12	3.2	18.2	-	-	-	-	-	-	-	-	-	-	-
15	" 32	12	3.0	18.1	1.7	43	135	11	4	-	-	-	-	-	-
16	" 34	12	2.9	18.1	-	-	-	-	-	-	-	-	-	-	-
17	" 36	12	2.8	18.2	1.7	41	111	8	2	-	-	-	-	-	-
18	" 38	12	2.8	18.2	-	-	-	-	-	-	-	-	-	-	-
19	" 40	11	2.5	18.1	-	-	-	-	-	-	-	-	-	-	-

W A T E R   Q U A L I T Y   D A T A

STATION	LOCATION	NO. SAMPLES	D O	TEMP. °C	BOD$_5$	COD	SOLIDS TOT.	SOLIDS SUSP.	SOLIDS VOL.	PHOSPHORUS TOT.	PHOSPHORUS SOL.	NITROGENS F.A.	NITROGENS KJEL.	NITROGENS NO$_2$	NITROGENS NO$_3$
G	MILE 40.5	16	6.5	19.2	1.5	45	124	13	3	0.15	0.10	0.19	0.50	0.011	0.02
20	" 42	12	6.7	18.1	-	-	-	-	-	-	-	-	-	-	-
H	" 43.8	15	6.0	19.3	1.5	45	116	12	4	0.15	0.09	0.19	0.60	0.01	0.02
21	" 44	12	8.6	18.1	-	-	-	-	-	-	-	-	-	-	-
22	" 46	12	8.5	18.0	-	-	-	-	-	-	-	-	-	-	-
23	" 48	12	8.3	17.9	1.5	43	95	12	3	-	-	-	-	-	-
24	" 52	12	8.0	17.9	1.5	40	115	16	3	-	-	-	-	-	-
25	CLAY LAKE	9	6.5	17.9	0.9	46	146	24	4	0.20	0.14	0.31	0.46	0.014	0.04
26A	" "	6	-	-	0.9	38	152	32	5	0.16	0.11	0.24	0.49	0.01	0.03
26	" "	8	6.7	17.9	1.2	41	139	57	9	0.13	0.08	0.22	0.62	0.010	0.03
27	" "	8	6.6	17.6	0.7	42	123	11	3	0.17	0.09	0.32	0.58	0.01	0.05
28	" "	7	5.3	16.8	0.9	45	113	8	3	0.21	0.18	0.23	0.43	0.01	0.08
29	" "	7	5.2	16.8	0.9	39	124	17	4	0.26	0.22	0.23	0.4	0.011	0.09

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N O T E: ALL VALUES MEASURED IN MG/L EXCEPT AS INDICATED.

FIG. A-1
WABIGOON RIVER
DISSOLVED OXYGEN PROFILE (at 635 cfs)
SEPT. 1968
(T=18°c)
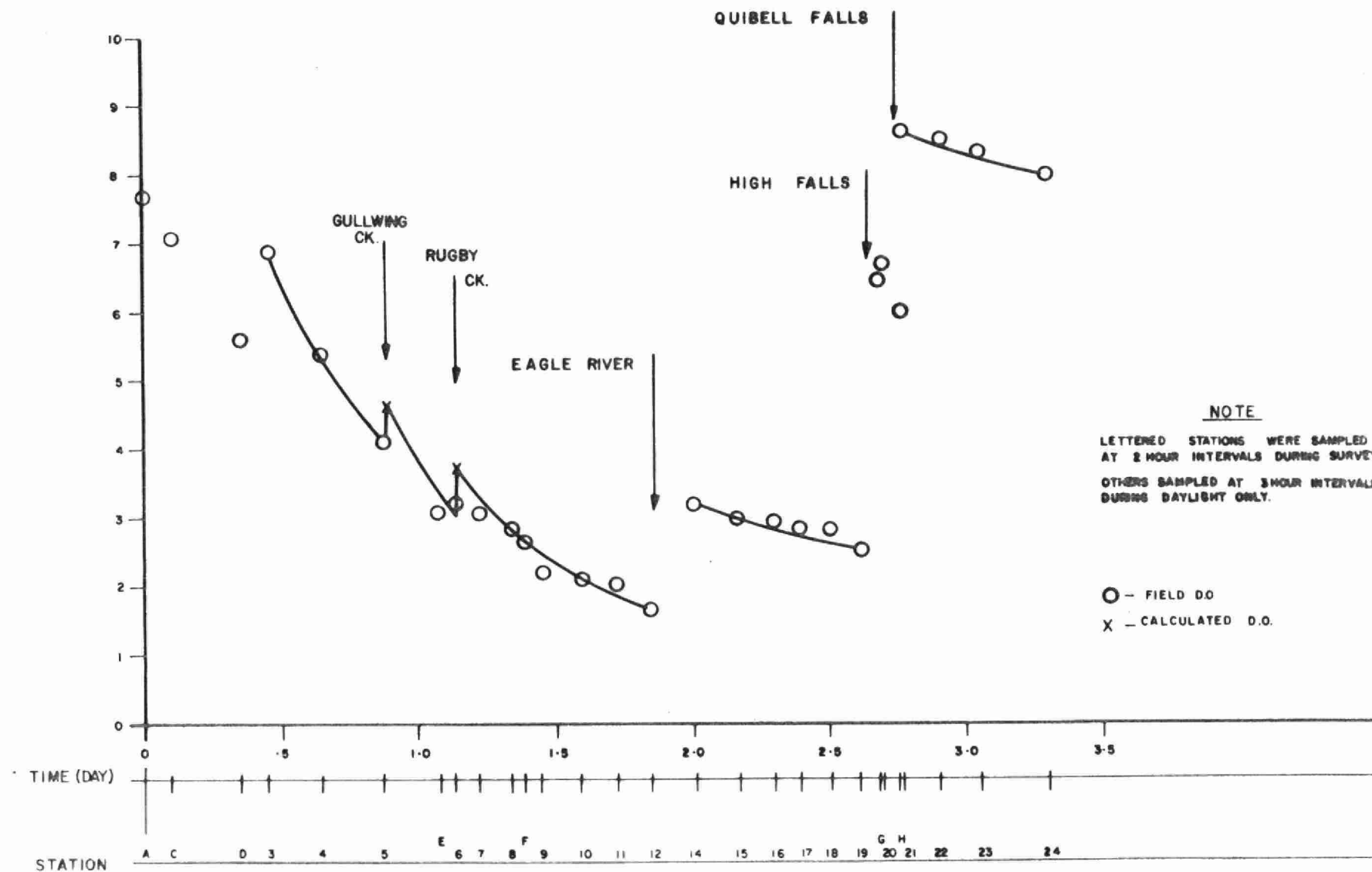
APPENDIX B

WASTE ASSIMILATION FORMULAE

AND

MATHEMATICAL MODEL

WASTE ASSIMILATION FORMULAE AND MATHEMATICAL MODEL

I WASTE ASSIMILATION FORMULAE

The following outlines the formulae used in the waste as-
similation calculations and the significance of the terms employed.

D_o = Dissolved oxygen deficit at the point of pollution or point of reference.

D_t = Dissolved oxygen deficit at any point, time "t" from the point of reference.

L_o = The first stage BOD at the point of reference.

k_1 = The laboratory rate of BOD stabilization (Ludzack).

K_r = The coefficient of BOD removal in the stream by physical removal and de-oxygenation (Base e).

K_d = The coefficient of deoxygenation (Base e).

K_2 = The coefficient of reoxygenation of the stream (Base e).

t = Time of travel (days)

W = Average sludge deposit width for reach under consideration (feet).

V = Average stream velocity for reach under consideration (feet per day).

S = Sludge demand (pounds per square foot per day).

With known values of D_o, L_o, K_r, K_d, K_2, W, V and S, a dissolved oxygen concentration may be computed for any time (t) downstream with the following equation:

$$D = \frac{K_d\,L_o}{K_2 - K_r}\,(e^{-K_r t} - e^{-K_2 t}) + D_o e^{-K_2 t} + \frac{WVS}{K_2}\,(1 - e^{-K_2 t})$$

Using D, the dissolved oxygen is calculated and plotted as a continuous curve against time to form a dissolved oxygen profile.

II MATHEMATICAL MODEL

The mathematical model for the Wabigoon River was established as follows:

Bottom sampling established that the river is almost completely covered with sludge for at least 28 miles downstream from Dryden and partially covered further downstream. The oxygen demand of the sludge was estimated to be 3.6 $g/m^2/day$. This estimate is based on OWRC oxygen uptake tests and test results reported by Stein and Denison.[1]

The coefficient of reaeration (K_2) was established using cross-sectional and streamflow velocity data collected during the study. A change in the physical characteristics resulting in slower stream velocities and greater water depths made a change in the reaeration

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[1] Stein, J.E. and Denison, J. G., In Situ Benthal Oxygen Demand of Cellulosic Fibres, Advances in Water Pollution Research, V. 3, 1966, pp 181 - 197.

coefficients necessary about 12 miles downstream from Dryden.

The coefficient of the deoxygenation K_d was established by plotting the logarithm of the BOD data in pounds per day against time of travel. This plot did not reveal the necessity for establishing a coefficient of BOD removal (K_r) and it could therefore be assumed that $K_r = K_d$. The laboratory rate of BOD stabilization (k_1) was established at the OWRC laboratory and used to calculate the first stage ultimate BOD.

The following values were thus obtained:

K_r = K_d = 0.40/day at 18°C

K_2 = .87/day (Stations 3 – 5) at 18°C

K_2 = 0.35/day (Stations 5 – 12) at 18°C

K_1 = 0.043/day at 20°C

Sludge demand = 0.72×10^{-3} pounds per square foot
per day = 3.6 g/m²/day.

With these coefficients, the measured waste loading and the initial dissolved oxygen level, the observed dissolved oxygen data between Stations 3 and 12 was successfully reproduced. At Station 12, the Eagle River contributes a substantial dissolved oxygen input. After this addition, the dissolved oxygen was modelled until Station 20. From this point, High Falls and then Quibell Falls contribute substantial amounts of oxygen and returned the dissolved oxygen in the Wabigoon River to acceptable levels.